



Bellcomm

955 L'Enfant Plaza North, S.W.
Washington, D. C. 20024

date: August 17, 1971
to: Distribution
from: A. Heiber
subject: Feasibility of High Gain Antenna
Pointing System - Case 320

B71 08020

ABSTRACT

This memorandum examines the feasibility of providing a high gain antenna pointing system with the object of providing continuous television coverage during the traverse of the Lunar Roving Vehicle (LRV).

This project was determined to be feasible. A solution is recommended which utilizes an Earth seeker and a two-axis gimbal system.

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ANTENNA POINTING SYSTEM (Bellcomm, Inc.)
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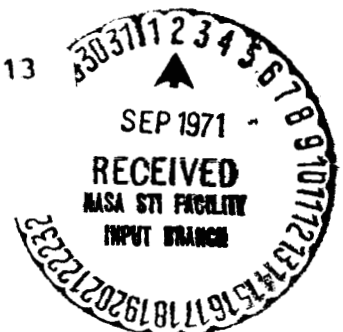
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MEMORANDUM FOR FILE

We have examined the problem of providing a continuous television coverage during the traverse of the LRV. Here we will examine possible solutions using the high gain antenna. The high gain antenna has a narrow, $\pm 2 \frac{1}{2}$ degree, beam width at the 1 db. points. At lunar distance the Earth subtends an angle of 2 degrees. Therefore, the antenna must be pointed at Earth within a 1.5 degree tolerance.

The Earth-Moon line drifts at 0.536 degrees per hour. The maximum time of travel of the LRV between stops is slightly less than one hour. If that were the only drift it would be clear that the antenna could be pointed at the Earth during stops and stabilized with a single two gimbal platform using gyroscopes. When gyro drift is taken into account, it is clear that in order to attain a drift rate of less than 1.0 degree per hour the gyro system would have to be expensive, heavy and complex. Considerable development would be required to assure that the system could survive the environment and function at the specified drift rate.*

A system that would point the high gain antenna using an Earth tracker was considered as more feasible and examined in detail.

The Earth tracker is an optical device that generates error signals when the Earth shine is not centered along its optical axis. The device can image the Earth on the focal plane by using optics or it may be possible to save weight by using a shadow mask arrangement.

*For a detailed summary of the considerations see, J. J. O'Connor, "On the Problem of Continuous Television During Rover Traverses", Bellcomm Memorandum to be released.



The device could operate in the visible or infrared regions. The infrared might have the advantage of producing a more uniformly centered image with a crescent illuminated Earth. The visible region would offer more energy. The size and energy of the source should preclude the need for spatial filtering.

The angle between the sun and the earth should be in excess of 20 degrees at any of the likely landing sites. This will permit a practical sunshade design.

Photoresistive sensors, such as cadmium sulphide or selenide have the requisite sensitivity but their response time is too slow (70 msec. or greater). Therefore, a silicon photovoltaic cell should be used. The photocell should probably be a quadcell or position cell. A quadcell is four cells on the same substrate. A position cell is one cell that gives an output proportional to image position.

A two axis gimbal configuration, nominally representing the LRV pitch-roll axes, will be adequate for pointing the antenna. A gimbal travel of ± 30 degrees appears to be adequate. The Earth zenith angle will account for 15 degrees and the LRV motion on rough mare will account for 15 degrees.

A choice must be made between a balanced and an unbalanced gimbal system. If the present optical sight is removed, (in favor of a simple gunsight or nothing) then the antenna would weigh about 2 lbs. at about 8 inches or more ahead of the gimbals. A counter-balance using the electronics, plus some piece of hardware that will be carried along anyway, would be required for a balanced gimbal configuration. If irreversible gimbals are employed, it would not be necessary to use a counterbalance. By irreversible gimbals, it is meant that the gimbals are driven through a worm gear such that the gimbals will appear mechanically locked to torques applied at the antenna. Inverted gimbals are preferred for irreversible gimbals to move the gimbal point closer to the c.g. Inverted gimbals refer to a gimbal system in which the inner gimbal is attached to the support structure and the outer gimbal is attached to the antenna. In a normal gimbal system the outer gimbal will be attached to the support structure. The gimbal configurations are illustrated in Figure 1.



Since the problem is to maintain an almost inertially fixed antenna vector, in theory very little power need be used. The forcing functions on the antenna are twofold; the coupling of gimbal angular velocity into the antenna mount through viscous friction in the bearing and back EMF in the torque motor (also treated as viscous friction) and the accelerations acting on the gimbaled, unbalanced mass.

The coupling of gimbal velocities is extremely small. The major error source is acceleration of unbalanced mass. Therefore, balancing the antenna platform is very important, especially in the preferred, free gimbal configuration. Maximum rigid body acceleration at the antenna mount was calculated to be 25 ft/sec² over the rough mare.

Flexible body motion at the antenna is reduced by increasing the stiffness of the support structure; however, the natural frequency is increased, placing a requirement for higher frequency response on the control system. If the project is undertaken, a trade-off study should be initiated to establish the optimum relationship between control response and support stiffness.

Separate simulations were run by Dr. I. Y. Bar-Itzhack and the author, using TRANSIM and CSSL III respectively. We examined the control system response for 25 seconds of LRV travel over rough mare. The simulation did not include accelerations at the gimbal point; however, the system was tested with a step torque input which should be in excess of that produced by the maximum rigid body acceleration

Figure 2 shows the response of the control system to angular rate disturbances transmitted by viscous friction during the 25 second travel of the LRV. Figure 3 shows the response to a step torque of 1/3 ft. lb. in addition to the rate disturbance. The angular rate and angle inputs are shown in Figures 4 and 5 respectively. The response to rate disturbances is minimal, 0.008 degrees. It is clear that acceleration of unbalance mass will dominate as an error source. The excursion due to this source can be limited, by reducing mass unbalance, of course, and by control system design, to be within the required tolerance.



CONCLUSION

Begging the question of desirability, it is clear from the foregoing that the project is feasible.

In summary I would make the following specific recommendations:

Earth Tracker:

That an optical Earth seeker be used in preference to a gyro stabilized system. Obviously, the Earth-Moon line is a more desirable reference than an inertial line for this purpose in addition to the gyro drift problem.

Optics should be preferred to a shadow mask for an efficient design at a slight weight penalty.

Sensing in the visible range, with the greater available energy, appears preferable to IR, for the given beamwidth of the antenna.

It appears that a silicon, photovoltaic quadcell or position cell should be the sensor.

A minimum 20° Earth-Moon-Sun angle should permit a straightforward sunshade design.

Gimbals:

A two-axis gimbal system representing the LRV pitch-roll axes should be used. Avoid an Az-El gimbal system.

A gimbal angle range of 30-40° appears adequate.

The gimbals should be mass balanced using a useful counterbalance (such as a tool).

Mass should be distributed to increase the moment of inertia about the active axes.

The gimbals should be free (as opposed to irreversible) and normal (as opposed to inverted).

The optical sight should be simplified or removed, if possible.



Forcing Functions:

The dominant disturbing force will be rigid and flexible body acceleration of the unbalanced, gimballed mass. The balance should be as fine as possible. The differential gimbal rate, coupled through viscous friction, will be a minimal disturbance.

Power Requirements:

The power required to maintain a nearly inertial orientation is theoretically negligible. The power demand is dominated by mass unbalance. About 12 watt per axis are required for stabilization with 0.33 ft. lb. unbalanced torque according to I. Y. Bar-Itzhack's simulation.

Support Structure:

A bipod, tripod or prestressed guywire arrangement should be considered to reduce flexible body motion of the support structure at the gimbals.

A. Heiber

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Attachments

Figures 1 - 5

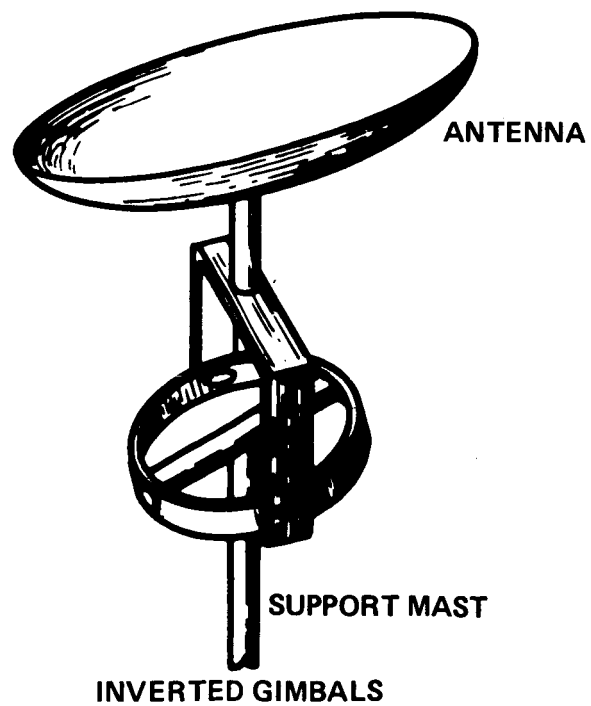
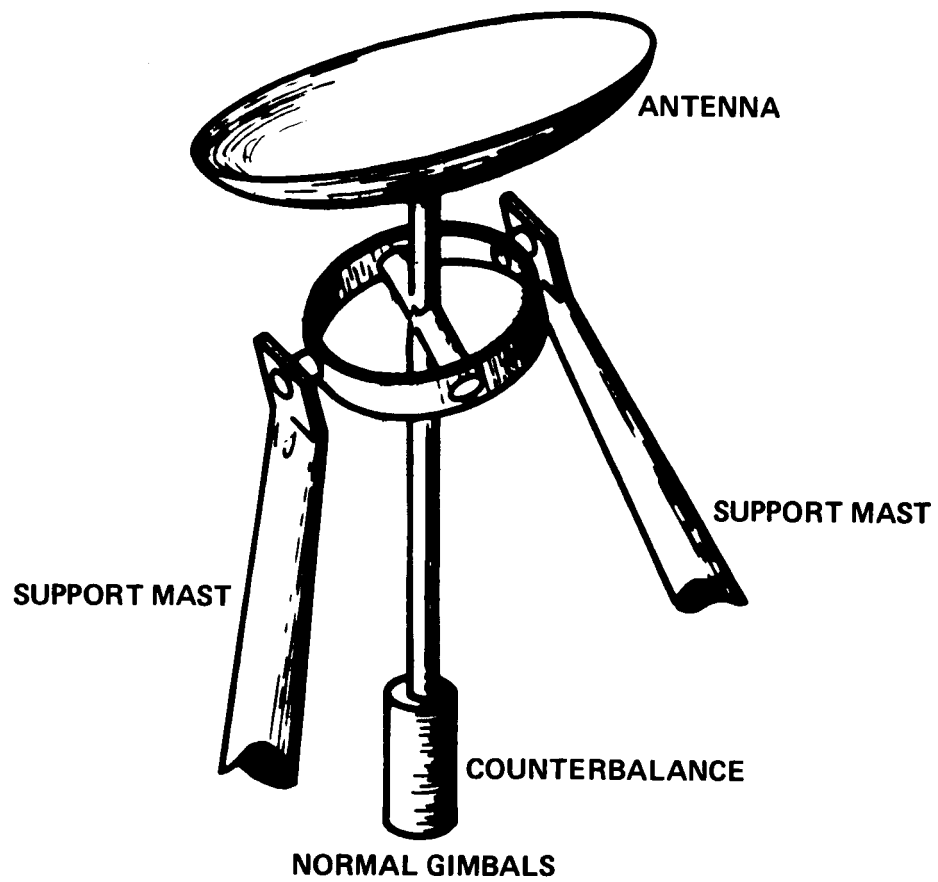


FIGURE 1 - GIMBAL CONFIGURATIONS

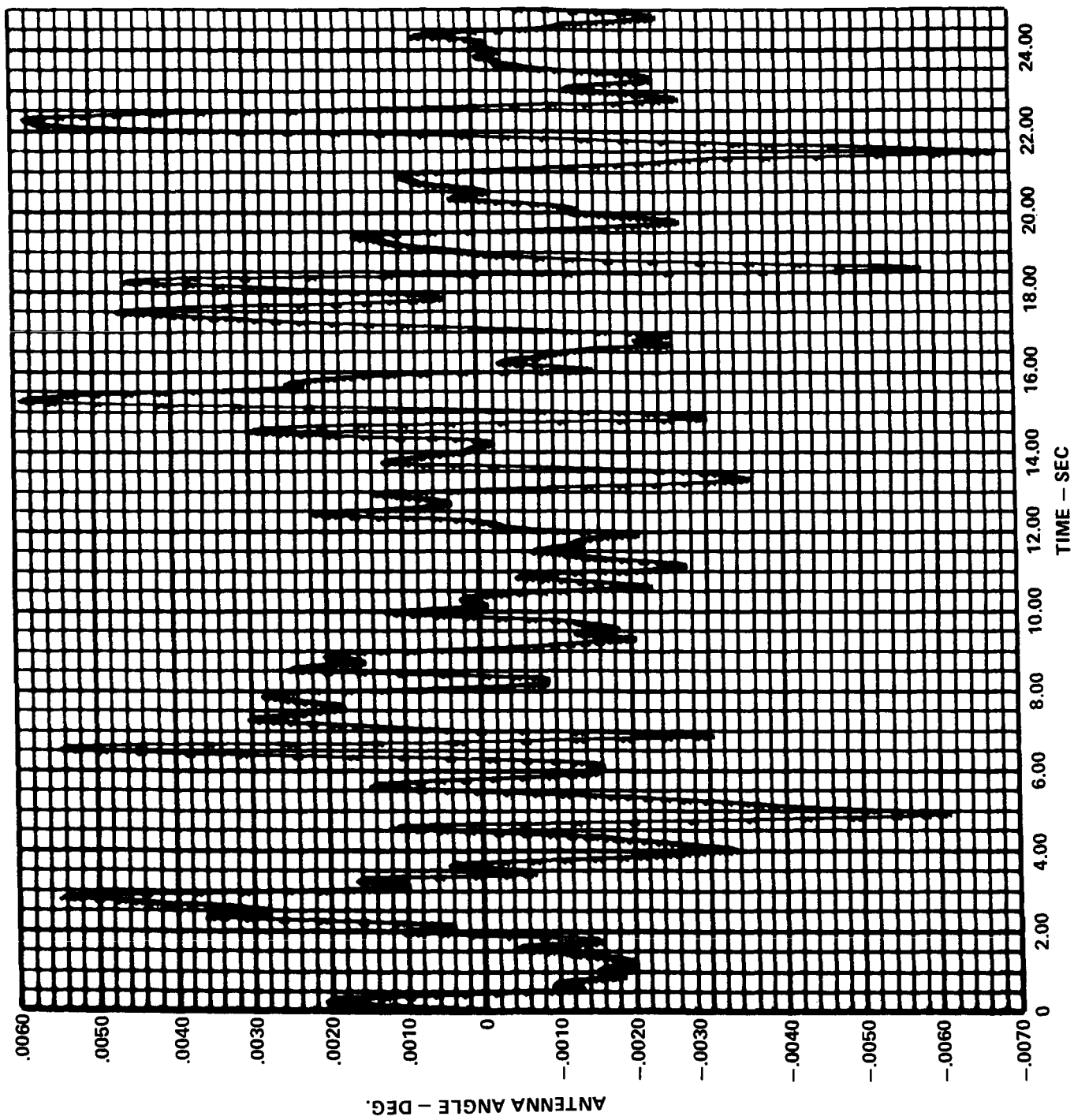


FIGURE 2 - ANTENNA RESPONSE TO LURAIN COUPLED THROUGH VISCOUS FRICTION

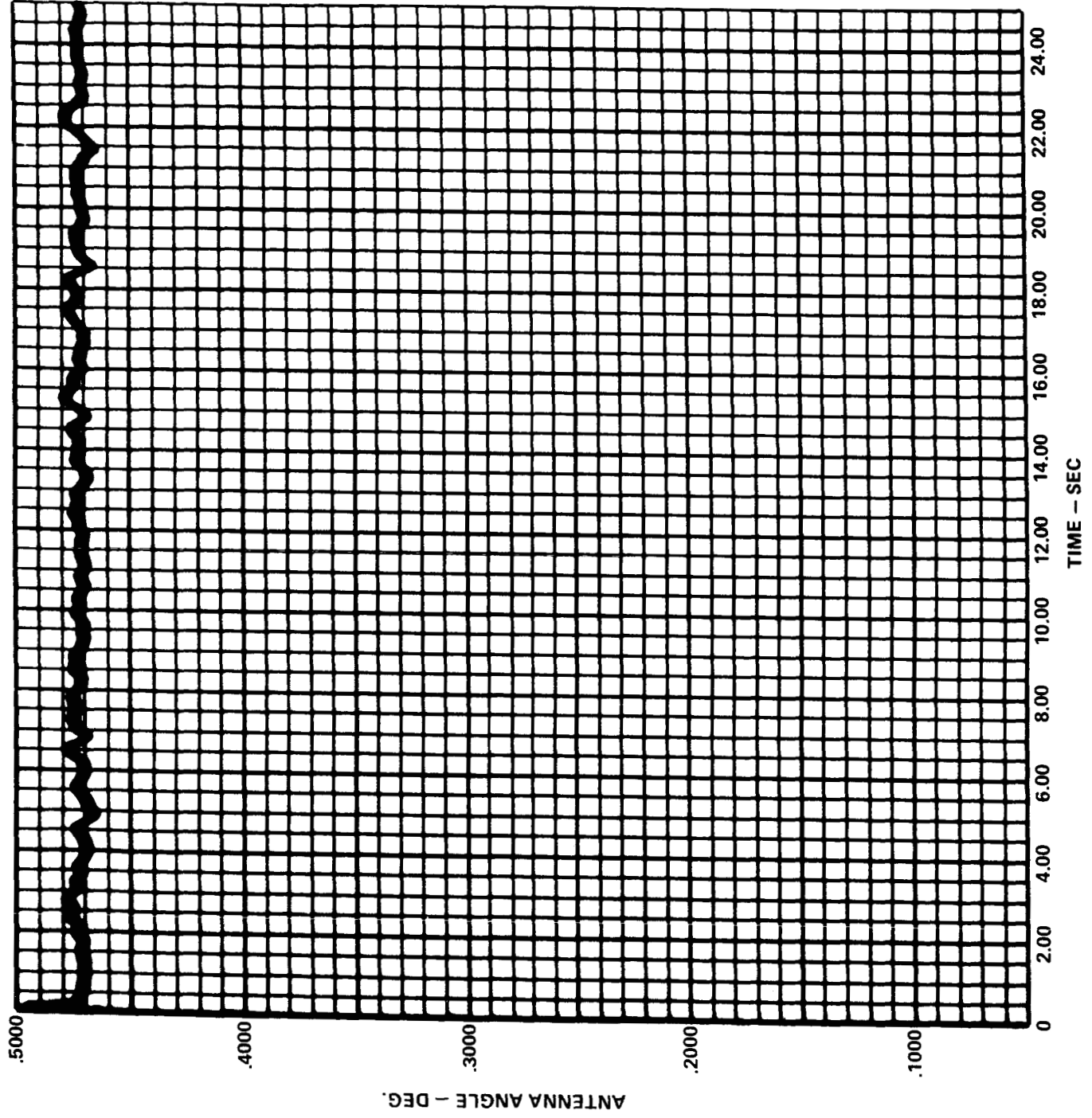


FIGURE 3 - RESPONSE TO STEP TORQUE AND ROUGH MARE

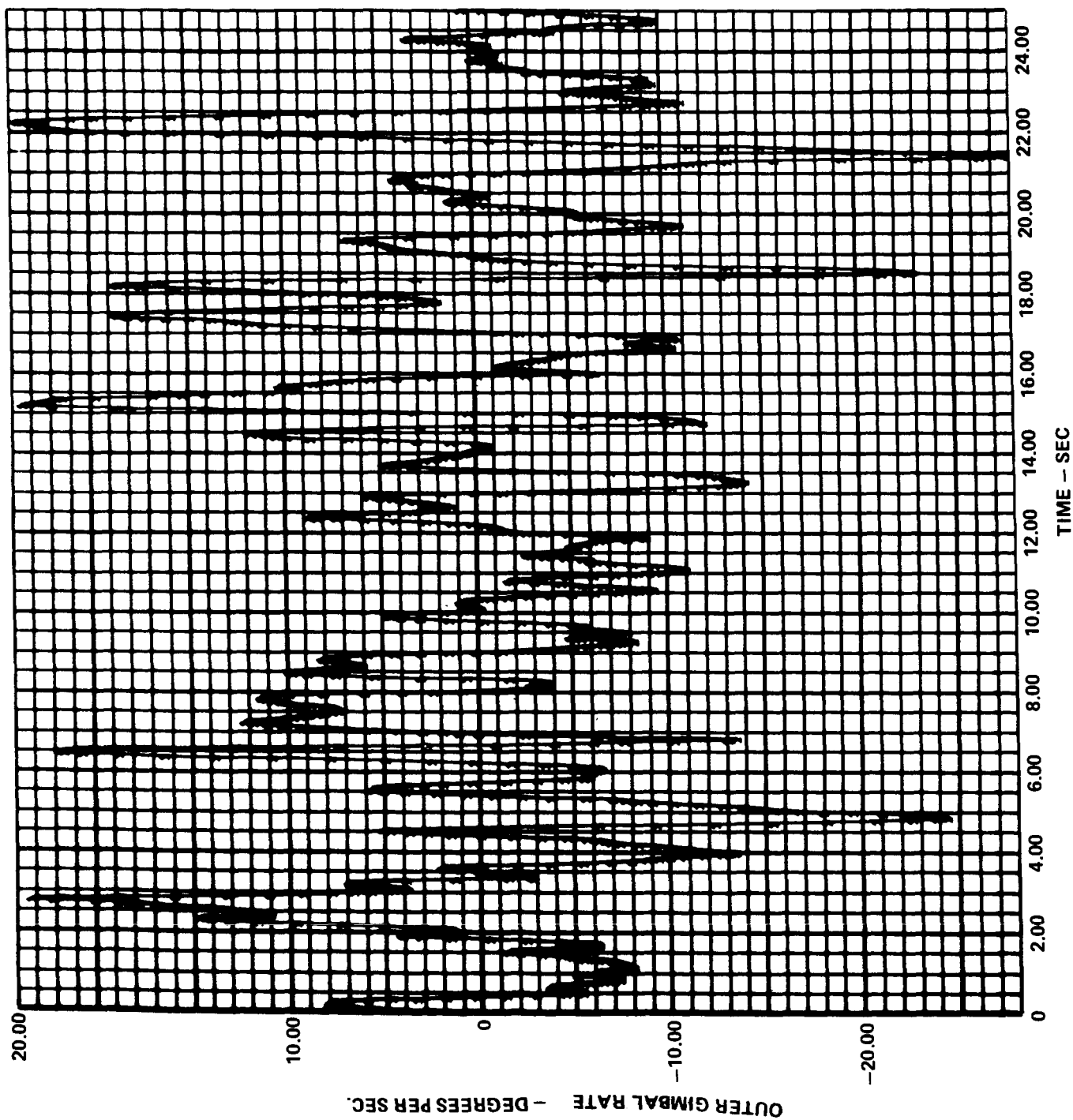


FIGURE 4 - GIMBAL RATE DUE TO LURAIN INPUT

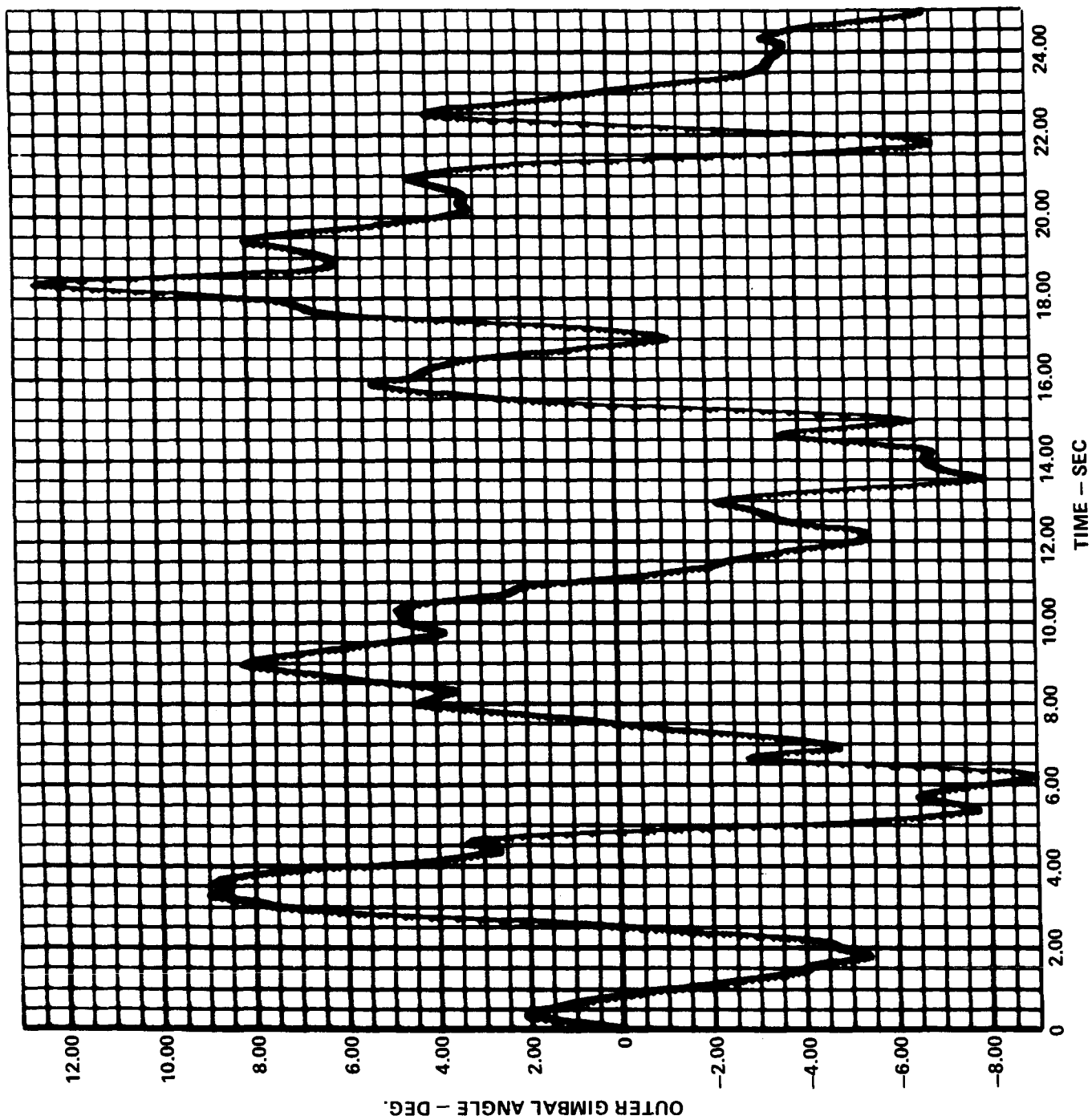


FIGURE 5 - GIMBAL ANGLE DUE TO LURAIN